

# SHEAR STRENGTH

## Introduction

Shear strength measurements are performed to test sediments and rocks to determine their stress-strain-time behavior. Some materials are brittle and exhibit little stress when strained (rocks); others are work-hardening (e.g., compacted clays and loose sands) or work-softening. In the clayey, soft, saturated marine sediments often measured for strength, stress decreases as the sediment is strained beyond a peak stress. The sediment yields (fails) at the peak stress, which can be defined as the sediment's strength. Shear strength or shear resistance of sediments is the most important aspect of slope stability. However, the shear strength values obtained by the Ocean Drilling Program (ODP) on the *JOIDES Resolution (JR)* do not alone allow any slope stability analysis. They represent a relative strength profile.

During the ODP, several different instruments were used to collect Shear Strength data: Motorized Torque Transducer, Automated Vane Shear, Wykeham-Farrance spring-type device, hand-held Torvane, and SoilTest Pocket Penetrometer. The tests were run on whole-core samples (into the end of the core), on split core samples (into the split core surface), or on remolded sediment samples.

## Data Acquisition

There were two types of strength tests conducted on the *JR* during the ODP: vane shear and penetrometer tests. Instruments that have been used to conduct vane shear tests include: the Motorized Torque Transducer, Automated Vane Shear, hand-held Torvane, and the Wykeham-Farrance device. Undrained shear strength was determined using a vane inserted into soft sediment and rotated until the sediment failed. The torque required to shear the sediment was related to the shear strength of the material. The pocket penetrometer measured compressive strength. The vertical strain measurement taken by the penetrometer can be related to shear strength; however, the strain value must be divided by 2 to obtain shear strength.

The automated vane shear (AVS) was the only shear data type that was collected by a computer-based data acquisition program. The first documented program for AVS system was deployed on Leg 154. The next major revision of the AVS data acquisition program was used to collect data starting Leg 170. This revision was in preparation for deployment of the Janus database. Measurements made with the torvane and the penetrometer had to be documented by the scientists or technicians doing the test.

There was no general calibration of the AVS system. However, vane dimensions and spring constants were important coefficients that were used to calculate strength. Occasional calibrations of those items were done, or when new ones were purchased. (The spring constant was a value relating the deflection angle to torque).

Additional information about ODP shear strength measurements can also be found in *Technical Note 26: Physical Properties Handbook*, Chapter 9.

## Archive

### Pre-Janus Archive

Early in the ODP, shear strength data were collected on logsheets which were sent back to ODP/TAMU at the end of each cruise. The data were entered into an S1032 database and the logsheets were microfilmed for archival storage. Data entry routines were implemented so that data entry could be done on the ship and the practice of collecting data on logsheets ended. Strength data were stored in the S1032 database through Leg 146. Starting around Leg 144, strength data were also saved in spreadsheet files that were brought back for archival on the ODP/TAMU servers. The AVS data acquisition program generated files with the vane shear data starting around Leg 154, but torvane and penetrometer data documentation was up to scientists collecting those data.

### Migration of Shear Strength data to Janus

The data model for Shear Strength data can be found in Appendix I. Since the data collected on the different instruments were very different, there are three sets of tables that contain strength data: Automated Vane Shear, Torvane and Penetrometer. Included are the relational diagram and the list of the tables that contain data pertinent to each of these data types, the column names and the definition of each column attribute. ODP Information Services Database Group was responsible for the migration of pre-Leg 171 data to Janus.

### Janus Shear Strength Data Format

AVS, PEN and TOR analyses can be retrieved from Janus Web using predefined queries. The Shear Strength (AVS/PEN/TOR) query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, run numbers, depth ranges, or latitude and longitude ranges. In addition, the Shear Strength query gives the user options to retrieve data by instrument, and output the raw data. Raw data could only be retrieved if the raw data were saved during data acquisition. It consists of the individual torque and strain values.

Table 1 below contains the data fields retrieved from the Janus database using the Janus Web predefined query with the Output Raw Data option. The first column contains the data item, the second column indicates the Janus table or tables where the data are stored, the third column is the Janus column name or the calculations used to produce the value. Appendix II contains additional information about the fields retrieved and the data format for the archived ASCII files.

Table 1. Shear Strength (AVS/PEN/TOR) with Output Raw Data option

<b>Item Name</b>	<b>Janus Table</b>	<b>Janus Column Name and Calculation</b>
<b>AUTOMATED VANE SHEAR</b>		
Leg	SECTION	leg
Site	SECTION	site
Hole	SECTION	hole
Core	SECTION	core
Type	SECTION	core_type
Section	SECTION	section_number
Top (cm)	AVS_SECTION_DATA	pp_top_interval x 100
Bottom (cm)	AVS_SECTION_DATA	pp_bottom_interval x 100
Depth (mbsf)	AVS_SECTION_DATA, DEPTH_MAP	DEPTH_MAP.map_interval_top + AVS_SECTION_DATA.top_interval.
Shear_Strength	AVS_SECTION_DATA	avs_strength
Max_Torque_Angle	AVS_SECTION_DATA	max_torque_angle
Residual_Strength	AVS_SECTION_DATA	residual_strength
Residual_Torque_Angle	AVS_SECTION_DATA	residual_torque_angle
Run_Number	AVS_SECTION	run_nun
Run_Date_Time	AVS_SECTION	run_date_time
Rotation_Direction	AVS_SECTION	direction
Rotation_Rate	AVS_SECTION	rotation_rate
Vane_ID	AVS_VANE_CALIBRATION	vane_id
Spring_ID	AVS_SPRING_CALIBRATION	spring_id
Raw_Data_Collected	AVS_SECTION	raw_data_collected
Torque	AVS_RAW_DATA	torque_angle
Strain	AVS_RAW_DATA	strain_angle
<b>PENETROMETER</b>		
Leg	SECTION	leg
Site	SECTION	site
Hole	SECTION	hole
Core	SECTION	core
Type	SECTION	core_type
Section	SECTION	section_number
Top_Interval(cm)	PEN_SAMPLE_DATA	pp_top_interval x 100
Depth(mbsf)	PEN_SAMPLE_DATA, DEPTH_MAP	DEPTH_MAP.map_interval_top + PEN_SAMPLE_DATA.pp_top_interval
Strength	PEN_SAMPLE_DATA	strength_reading
Run_Date_Time	PEN_SECTION_DATA	run_date_time
Rotation_Direction	PEN_SECTION_DATA	direction
Adapter	PEN_SECTION_DATA	adapter_used
Comment	PEN_SECTION_DATA	Comments
<b>TORVANE</b>		
Leg	SECTION	leg
Site	SECTION	site
Hole	SECTION	hole
Core	SECTION	core
Type	SECTION	core_type
Section	SECTION	section
Top_Interval(cm)	TOR_SAMPLE-DATA	pp_top_interval x100
Depth(mbsf)	TOR_SAMPLE_DATA, DEPTH_MAP	DEPTH_MAP.map_interval_top + TOR_SAMPLE_DATA.pp_top_interval
Strength	TOR_SAMPLE_DATA	strength_reading
Run_Date_Time	TOR_SECTION_DATA	run_date_time
Rotation_Direction	TOR_SECTION_DATA	direction
Range	TOR_SECTION_DATA	range
Comment	TOR_SECTION_DATA	comments

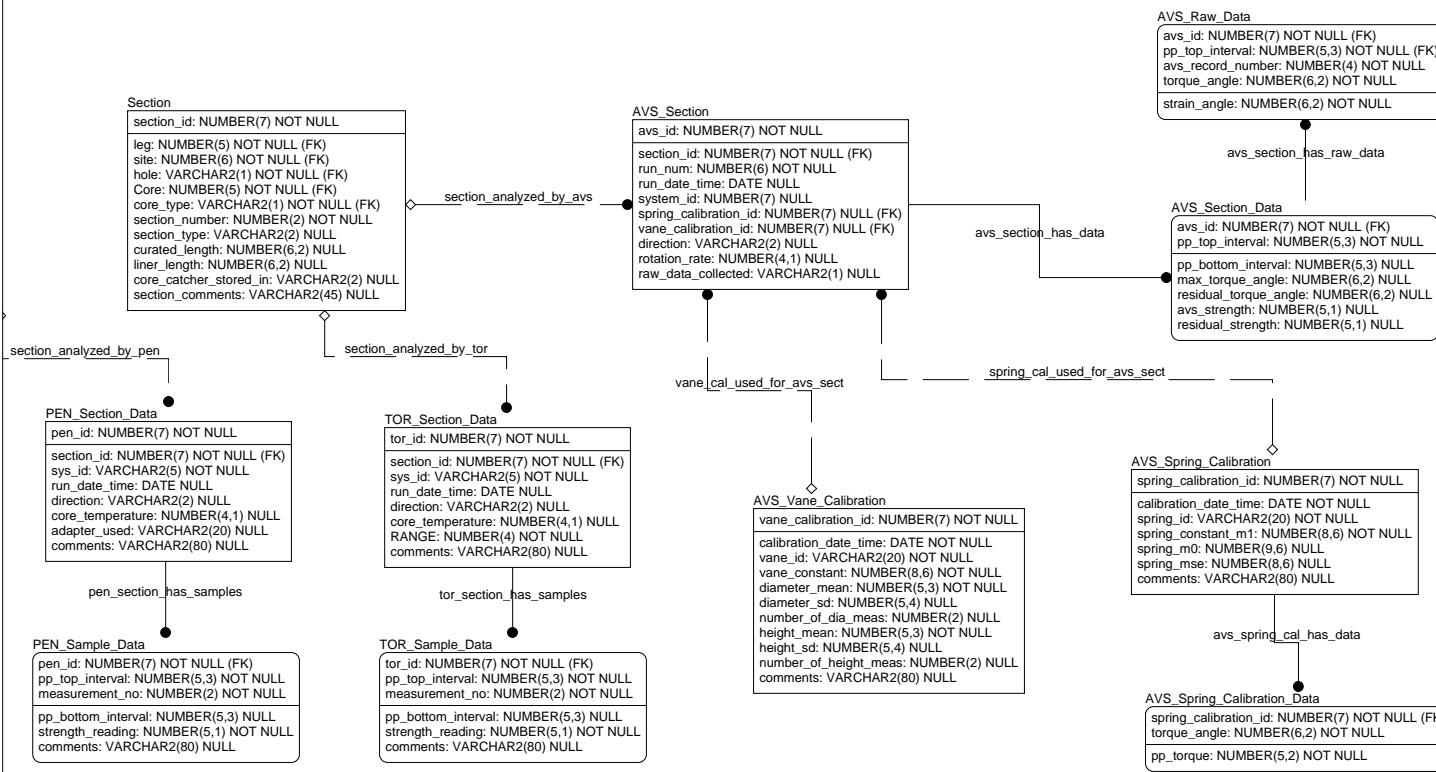
## **Data Quality**

The verification of the entire shear strength data sets were not completed due to time constraints. The variety of instruments and the lack of data acquisition programs for data collection made it more difficult to verify the measurements. To complete the verification, more research would be necessary to find the documentation about equipment and procedures used to collect these data, and verify the data using logsheets and comparison with the reported data in the Initial Report volumes.

Most data collected after the Janus database was operational on Leg 171 were verified as part of the Janus data management and verification procedures (see Metadata Introduction). Occasionally, torvane and penetrometer data were collected, but data files were not transferred to ODP/TAMU at the end of the leg. Some verification was done on the pre-Leg 171 data; however, if there is a discrepancy between the database and data in the Initial Report volumes, the published data should be considered more reliable.

## **Reference**

Blum, P., 1997, Physical Properties Handbook: A guide to the shipboard measurement of physical properties of deep-sea cores, ODP Tech. Note 26.



## APPENDIX I: Janus Data Model – Shear Strength

SHEAR STRENGTH – Automated Vane Shear, Penetrometer, Torvane		
Table Name	Column Name	Column Comment
AVS_Section	avs_id	Unique Oracle-generated sequence number for each AVS analysis run.
	section_id	Unique Oracle-generated sequence number to identify each section.
	run_num	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	run_date_time	Timestamp when analysis was run.
	system_id	Unique identifier for a system of equipment on the ship.
	spring_calibration_id	Unique Oracle-generated sequence number for each spring calibration.
	vane_calibration_id	Unique Oracle-generated sequence number for each vane calibration.
	direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.
	rotation_rate	The rate of rotation of a vane in degrees per minute.
	raw_data_collected	Raw data flag to indicate whether raw data for a measurement was saved. Valid values - Y or N.
AVS_Section_Data	avs_id	Unique Oracle-generated sequence number for each AVS analysis run.
	pp_top_interval	The top interval of a measurement in meters measured from the top of a section.
	pp_bottom_interval	The bottom interval of a measurement in meters measured from the top of a section.
	max_torque_angle	The maximum torque angle that is achieved before shearing occurs in the sediment while performing a Vane Shear measurement.
	residual_torque_angle	The residual angle of the sediment after shearing has occurred for a Vane Shear measurement.
	avs_strength	Calculated strength value. Added July 2002 in order to enter AVS results when calibration information is not available.
	residual_strength	Calculated residual strength value. Added July 2002 in order to enter AVS results when calibration information is not available.
AVS_Raw_Data	avs_id	Unique Oracle-generated sequence number for each AVS analysis run.
	pp_top_interval	The top interval of a measurement in meters measured from the top of the section.
	avs_record_number	Counter used to uniquely identify a strain-torque pair for AVS raw data. The counter is needed because neither torque or strain is unique.
	torque_angle	Torque angle for an AVS measurement, in degrees.
	strain_angle	Strain angle for an AVS measurement, in degrees.
AVS_Spring_Calibration	spring_calibration_id	Unique Oracle-generated sequence number for each spring calibration recorded for the AVS system.
	calibration_date_time	Timestamp when calibration was done.
	spring_id	Unique identifier for each spring used in vane shear analysis.
	spring_constant_m1	The slope of the linear regression when calibrating a spring used for AVS analyses, in degrees/kg-cm.
	spring_m0	The intercept of the linear regression when calibrating a spring used for AVS analyses, in degrees.
	spring_mse	The mean squared error calculated when calibrating a spring for AVS analyses.
	comments	General comments
AVS_Spring_Calibration_Data	spring_calibration_id	Unique Oracle-generated sequence number for each spring calibration recorded for the AVS system.
	torque_angle	Torque angle for an AVS measurement, in degrees.
	pp_torque	Torque associated with a spring in kg-cm.

## **SHEAR STRENGTH – Automated Vane Shear, Penetrometer, Torvane**

<b>Table Name</b>	<b>Column Name</b>	<b>Column Comment</b>
<b>AVS_Vane_Calibration</b>	vane_calibration_id	Unique Oracle-generated sequence number for each vane calibration recorded for the AVS system.
	calibration_date_time	Timestamp when calibration was done.
	vane_id	Unique identifier for each vane used in vane shear analysis.
	vane_constant	The area of surface of a cylinder (the shear plane) that a vane creates as it rotates during a vane shear measurement.
	diameter_mean	Mean diameter of a vane shear vane, in mm.
	diameter_sd	Standard deviation of the diameter of a vane shear vane, in mm.
	number_of_dia_meas	Number of diameter measurements taken of a vane.
	height_mean	The mean height measured for a vane used for Vane Shear analysis, in mm.
	height_sd	The standard deviation of the height measurements made on a vane used for Vane Shear analysis, in mm.
	number_of_height_meas	The number of measurements made to calibrate a vane shear vane.
comments		
<b>PEN_Section_Data</b>	pen_id	Unique Oracle-generated sequence number for each PEN analysis run.
	section_id	Unique Oracle-generated sequence number to identify each section.
	sys_id	Identifier for the system used. Valid value = PEN.
	run_date_time	Timestamp when analysis was run.
	direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.
	core_temperature	Temperature of the core in °C.
	adapter_used	The adaptor used for Penetrometer measurements in the physical properties laboratory.
	comments	General comments
<b>PEN_Sample_Data</b>	pen_id	Unique Oracle-generated sequence number for each PEN analysis run.
	pp_top_interval	The top interval of a measurement in meters measured from the top of the section.
	measurement_no	The number of the measurement taken, used to differentiate multiple measurements taken at the same interval.
	pp_bottom_interval	The bottom interval of a measurement in meters measured from the top of the section.
	strength_reading	The value of the strength reading, no units given.
	comments	General comments
<b>TOR_Section_Data</b>	tor_id	Unique Oracle-generated sequence number for each TOR analysis run.
	section_id	Unique Oracle-generated sequence number to identify each section.
	sys_id	Identifier for the system used, Valid value = TOR for torvane.
	run_date_time	Timestamp when analysis was run.
	direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.
	core_temperature	Temperature of the core in °C.
	range	Range of torvane - 200, 1000 or 2000 in g/cm²
	comments	General comments
<b>TOR_Sample_Data</b>	tor_id	Unique Oracle-generated sequence number for each TOR analysis run.
	pp_top_interval	The top interval of a measurement in meters measured from the top of the section.
	measurement_no	The number of the measurement taken, used to differentiate multiple measurements taken at the same interval.

## **SHEAR STRENGTH – Automated Vane Shear, Penetrometer, Torvane**

<b>Table Name</b>	<b>Column Name</b>	<b>Column Comment</b>
	pp_bottom_interval	The bottom interval of a measurement in meters measured from the top of the section.
	strength_reading	The value of the strength reading, no units given.
	comments	General comments

<b>Section</b>	section_id	Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber.
	leg	Number identifying the cruise for which data were entered into the database.
	site	Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.
	hole	Letter identifying the hole at a site from which a core was retrieved or data were collected.
	Core	Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.
	core_type	A letter code identifying the drill bit/coring method used to retrieve the core.
	section_number	Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.
	section_type	Used to differentiate sections of core (S) from core catchers (C). Previously, core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.
	curated_length	The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.
	liner_length	The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.
	core_catcher_stored_in	Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.
	section_comments	Comments about this section.

Appendix II. Description of data items from Shear Strength query with Output Raw Data option.

Item Name	Column Description	Format
<b>AUTOMATED VANE SHEAR</b>		
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. MAD analyses were made on samples taken from the sections. Core Catcher sections identified as "CC."	Integer 2 or Text 2
Top (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Bottom (cm)	The location of the bottom of a sample in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the sample location.	Decimal F7.3
Shear_Strength	Calculated value of the strength of the sediments.	Decimal F5.1
Max_Torque_Angle	The maximum torque angle that is achieved before shearing occurs in the sediment while performing a Vane Shear measurement.	Decimal F6.2
Residual_Strength	Calculated value of the residual strength of the sediments.	Decimal F5.1
Residual_Torque_Angle	The residual angle of the sediment after shearing has occurred for a Vane Shear measurement.	Decimal F6.2
Run_Number	Number identifying a run generated by the data acquisition software.	Integer 6
Run_Date_Time	Timestamp when the measurement was taken.	Text 16 (yyyy-mm-dd hh:mm)
Rotation_Direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.	Text 2
Rotation_Rate	The rate of rotation of a vane in degrees per minute	Decimat F4.1
Vane_ID	Descriptive name given to vanes for identification.	Text 20
Spring_ID	Descriptive name given to springs for identification	Text 20
Raw_Data_Collected	Flag indicating whether the data acquisition program saved the raw torque and strain measurements. Valid values Y or N.	Text 1
Torque	Torque angle for an AVS measurement, in degrees.	Decimal F6.2
Strain	Strain angle for an AVS measurement, in degrees.	Decimal F6.2

Item Name	Column Description	Format
<b>PENETROMETER</b>		
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. MAD analyses were made on samples taken from the sections. Core Catcher sections identified as "CC."	Integer 2 or Text 2
Top_Interval (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the sample location..	Decimal F7.3
Strength	Calculated value of the strength of the sediments	Decimal F5.1
Run_Date_Time	Timestamp when the measurement was taken.	Text 16 (yyyy-mm-dd hh:mm)
Rotation_Direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.	Text 2
Adapter	The adaptor used for Penetrometer measurements.	Text 20
Comment	General comments.	Text 80

<b>TORVANE</b>		
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1

<b>Item Name</b>	<b>Column Description</b>	<b>Format</b>
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. MAD analyses were made on samples taken from the sections. Core Catcher sections identified as "CC."	Integer 2 or Text 2
Top_Interval (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the sample location.	Decimal F7.3
Strength	Calculated value of the strength of the sediments	Decimal F7.3
Run_Date_Time	Timestamp when the measurement was taken.	Text 16 (yyyy-mm-dd hh:mm)
Rotation_Direction	Direction of measurement relative to a section of core. Valid values: X - perpendicular to core axis and perpendicular to split surface, Y - perpendicular to core axis and parallel to split surface, Z - parallel to core axis.	Text 2
Range	Range of torvane - 200, 1000 or 2000 in g/cm <sup>2</sup>	Integer 4
Comment	General comments.	Text 80